中國科學技術史

李約瑟著

SCIENCE AND CIVILISATION IN CHINA

BY

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  - (v) Leeboards and centre-boards
- (2) Oars
  - (i) Rowing and the handled oar
  - (ii) Sculling and the self-feathering 'propeller'
  - (iii) The human motor in East and West

(*g*) Control; steering
- (1) From steering-oar to stern-post rudder in the West
- (2) China and the axial rudder
- (3) Balanced and fenestrated rudders

(*h*) Ancillary techniques

(*i*) Conclusions

30 MILITARY TECHNOLOGY

(*a*) Introduction

(*b*) The art of war in Chinese literature
- (1) Battle accounts
- (2) The military theoreticians
- (3) Technical compilations

(*c*) Shock weapons (swords, spears, lances, etc.)

(*d*) Projectile weapons, I
- (1) Bows in Asian armies
- (2) Crossbows and their trigger mechanisms
- (3) Multiple-projectile crossbows
- (4) Repeating or 'magazine' crossbows
- (5) The crossbow in East and West

(*e*) Armour and caparison

(*f*) Techniques of cavalry
- (1) The invention of the stirrup and its spread
- (2) Saddle, bit and horse-shoe
- (3) The Heavenly Horses of Ferghana

(*g*) Techniques of fortification
- (1) The Mohist contribution

(*h*) Projectile weapons, II
- (1) Catapults; the spring, the sinew and the swape
- (2) The coming of explosive weapons

(*i*) Techniques of communication (flags, beacons, kites, homing birds, etc.)

(*j*) General considerations
- (1) Significance of the horse-archer
- (2) Comparison of the Han and Roman armies; their single contact
- (3) Military techniques and the relations of social classes in East and West
- (4) Mongol and medieval armies
- (5) Poliorcetics in East and West
- (6) Cycles of offence and defence; the Chinese culture-area compared with the Western world

[*From this point onwards, the work is still in preparation, though some sub-sections have already been written. Sub-section titles have not yet, therefore, been definitely established. It will be understood that the headings given below are only tentative; they are intended only to give a rough idea of the contents of each section.*]

31 TEXTILE TECHNOLOGY

The chief plant fibres used in Chinese civilisation

Silk technology: reeling and winding, twisting and doubling machinery

Ancient looms in picture and literary reference

Invention and use of the drawloom in the early Han

Use of the paper-mulberry

Late introduction of cotton and its associated techniques. The cotton loom

Application of water-power to spinning in the Yuan

Dyeing and fulling

32 PAPER AND PRINTING

Discovery of paper in the Han

The coming of block printing in the Thang

Invention of movable-type printing in the Sung

Records of the journeys of paper and printing to the West

VOLUME 5. CHEMISTRY AND INDUSTRIAL CHEMISTRY

33 ALCHEMY AND CHEMISTRY

First indications of alchemy in Chhin and early Han; relations with Taoism

Wei Po-Yang; the beginnings of alchemical literature in the later Han (+2nd century)

Ko Hung (+4th century); systematiser of Chinese alchemy

Problem of the relationship between Chinese and Western alchemy; the role of the Arabs

Alchemy in the *Tao Tsang*; account of the knowledge of the Thang and Sung alchemists

Decline in the Yuan and Ming periods; chemical technologies alone flourishing, on traditional lines

34 CHEMICAL TECHNOLOGY

Non-alchemical chemistry in ancient China

Discovery of gunpowder during the Thang; its military applications from the beginning of the Sung (igniters, grenades, mines, rockets, fire-lances, etc.); its relation to the development of barrel-guns in late Sung, Yuan and Ming; and its transmission to Europe

Other chemical technologies in medieval China

35 CERAMIC TECHNOLOGY

History of pottery, porcelain, felspathic glazes, etc.

36 MINING AND METALLURGY

Ancient Chinese bronze and bronze-casting. Metallurgical formularies in Han books

Ancient iron technology; the mastery of cast iron in the Han; iron ploughs and sword forging

Metallurgy of the precious metals

Knowledge of coal in China and tentatives at coke for smelting. Types of smelting furnaces. The great Ming metallurgical compendium

Mining of tin and zinc. Brass and other alloys, some unknown to the West till the +18th century

37 THE SALT INDUSTRY

Sea-salt and its refining

The invention of the technique of deep-drilling in the Han and its use for the exploitation of the Szechuanese fields of brine and natural gas

Salt nomenclature

VOLUME 6. BIOLOGY, AGRICULTURE AND MEDICINE

38 BOTANY

Botany and plant sciences in the great series of pharmaceutical compendia

Development of the classification system

Special monographs in the Sung

Discovery of sex in plants; plant abnormalities, etc.

39 ZOOLOGY

Zoology and comparative physiology in the great series of pharmaceutical compendia

Development of the classification system

Special monographs in the Sung and Ming

40 BIOCHEMICAL TECHNOLOGY (NUTRITION AND FERMENTATIONS)

Empirical knowledge of effects of micro-organisms

Differences in the fermenting organisms used as between China and the West

Traditional use of complex pharmaca to prevent fermentation deviations. Relation to the introduction of hops to Europe
The problem of distillation and the discovery of alchohol
Empirical knowledge of deficiency diseases in the Yuan period

41 AGRICULTURE, ANIMAL HUSBANDRY, AND FISHERIES
Characteristics of Chinese agriculture. Survey of the principal landmarks in Chinese agricultural literature, from the fragmentary Han works onwards
Agricultural tools and practices; irrigation, crop rotation, etc.
Crop plants used
Ploughs and their relations with European ploughs and other machines. Re-invention of the seed-drill plough
Sung agricultural and horticultural monographs
Use of human manure and composting
Animal breeding—horse, buffalo, camel. Animal health. Relations with nomadic pastoralism
Cultivation of fish-ponds from early times; Han treatises on fisheries. Fishing methods; the white board technique and the domestication of the cormorant. Sea fisheries.

42 AGRICULTURAL ARTS
Economic entomology; the invention of the biological control of insect pests. Insecticides in the Han. Measures against locusts
Rural industries; the insect wax industry. Lacquer. Vegetable oils. Sugar. Tea

43 THE INSTITUTES OF MEDICINE: ANATOMY, PHYSIOLOGY, AND EMBRYOLOGY
The story of Chinese anatomy
Anatomical diagrams and the early rise of forensic medicine. Progress of dissection in Han and Sung
Physiological ideas in the medical classics
Embryological ideas, influenced by Buddhism

44 MEDICINE
Survey of the principal landmarks in the vast sea of Chinese medical literature
The traditional systems of pathology and therapy

Diagnosis and prognosis
The characteristic emphases: (*a*) the observation of the pulse; (*b*) acupuncture and cautery
The ancestor of vaccination, variolation, a Sung invention
Ophthalmology
Obstetrics and gynaecology
Paediatrics
The relative backwardness of surgery
Social medicine
The status of the medical practitioner

45 PHARMACEUTICS
Provisional assessment of the value of drugs in the traditional pharmacopoeia. Description of a few of the most important (e.g. ephedrine)
Divergences from occidental materia medica (e.g. a drug from amphibia instead of digitalis)
The early use of mineral remedies

VOLUME 7. THE SOCIAL BACKGROUND

46 RETROSPECTIVE SURVEY OF THE CHARACTERISTICS OF CHINESE SCIENCE
Perennial preoccupations
Empirical genius and primitive theory
Organic philosophy and the absence of atomic machinery
Order but not Law
Short-circuiting Aristotelian logic
The Chinese and the irrational
The lack of interest in abstract systematisation
The humanist emphasis

47 GEOGRAPHICAL FACTORS

48 SOCIAL AND ECONOMIC FACTORS
The passing over of Bronze-Age Proto-Feudalism into Feudal Bureaucratism, and all that that implied

The extent to which the forms of Chinese Society were determined by the hydrology of its environment; the constant need for works of hydraulic engineering (irrigation, flood protection, tax-grain transportation)

Inhibition of capital accumulation by the merchants, and of its application to industrial ventures

49 PHILOSOPHICAL AND IDEOLOGICAL FACTORS

Language as a limiting factor

Logic as a limiting factor

Technical terminology as a limiting factor

Attitudes to Time and Change

Antagonism between manual and mental work

Family property in technical ideas

The role of religion

Individualism and democracy

50 GENERAL CONCLUSIONS

[*This final volume will contain unified bibliographies and indexes of all the previous volumes* (*see vol. 1, pp. 20ff., 249ff.*).]

1. PREFACE

THE HISTORY OF SCIENCE is now more and more widely recognised as an element of cardinal importance in the history of human civilisation. In the course of this development it has been natural for Western Europeans to work backward from modern science and technology, tracing the evolution of scientific thought to the experiences and achievements of Mediterranean antiquity. An abundant literature exists in which we may read of the foundations laid by Greek and Roman thinkers, mathematicians, engineers and observers of Nature. Earlier works, such as William Whewell's *History of the Inductive Sciences* of 1837, betray a bland unconsciousness of even the existence of the contributions of other peoples to the history of man's understanding of his environment. Since then, the debt of developed scientific thought to the ancestral pioneering of the Egyptians, as also to the work of the ancient inhabitants of the Fertile Crescent, Sumerians, Babylonians, the Hittites and others, has been better recognised and explored. Owing partly to circumstances which brought Europeans into close contact with Indian culture from the days of Megasthenes to those of Macaulay, some justice (still insufficient) has been done to Indian achievements, though here there are difficult problems of chronology which continue to prevent the appearance of a clear picture. And still today the contribution of the Far East, and especially of its oldest and most central civilisation, that of the Chinese, to science, scientific thought and technology, remains unrecognised and clouded in obscurity. The very term 'Far East', which I shall not use again in this book, but which springs spontaneously to the written page, exemplifies that fundamental insularity of outlook which it is so difficult for Europeans, even those who have the best intentions, to discard. The scientific contribution of Asia, and in particular of the 'Central Country', China, is the theme of this work.

What exactly did the Chinese contribute, in the various historical periods, ancient and medieval, to the development of Science, Scientific Thought and Technology? The question can still be asked for later periods, though after the coming of the Jesuits to Peking in the early 17th century, Chinese science gradually fused into the universality of modern science. Why should the science of China have remained, broadly speaking, on a level continuously empirical, and restricted to theories of primitive or medieval type? How, if this was so, did the Chinese succeed in forestalling in many important matters the scientific and technical discoveries of the *dramatis personae* of the celebrated 'Greek miracle', in keeping pace with the Arabs (who had all the treasures of the ancient western world at their disposal), and in maintaining, between the 3rd and the 13th centuries, a level of scientific knowledge unapproached in the west? How could it have been that the weakness of China in theory and geometrical systematisation did not prevent the emergence of technological